MEDICAL PRACTICE

Clinical Topics

Self-monitoring of blood glucose in diabetic pregnancy

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Summary and conclusions

Admission to hospital is usually recommended to achieve the best possible diabetic control during pregnancy. We have used blood glucose monitoring at home to find out if patients can achieve equally good control outside hospital. Twenty-five consecutive diabetic patients were studied, of whom 20 had taken insulin before pregnancy. Six of their 14 previous pregnancies had ended in perinatal death. The 25 women performed 4247 blood glucose measurements during their pregnancies. Overall the mean blood glucose concentration was 7·1 mmol/l (128 mg/100 ml); before meals the mean was 6·5 mmol/l (117 mg/100 ml). Mean concentrations were lower in the third trimester, but at no stage was control in hospital significantly better than at home. The mean hospital stay before delivery was 22 days, and all patients had live babies.

Monitoring blood glucose concentrations at home produces greater understanding and motivation among patients, improves control early in pregnancy, and shortens time spent in hospital.

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Introduction

Over the past 30 years better management has reduced the perinatal mortality of diabetic pregnancy from over 30% to below 5%. Largely responsible has been the attempt to maintain maternal blood glucose concentrations as close to normal as possible.[1-7] There are many difficulties in achieving and monitoring this degree of control, and therefore it is often suggested that pregnant diabetics should be admitted to hospital during the last trimester to allow frequent measurements of blood glucose concentrations.[2 7] Such prolonged confinement is often unwelcome to the mother, particularly when there is a young family at home, and may waste hospital beds, which are expensive and in short supply.

By monitoring blood glucose concentrations at home[8 9] and with an organised team approach to the management of the pregnant diabetic we tried to maintain optimum metabolic control without prolonged admission to hospital. We tried to operate this programme from the time of diagnosis of pregnancy and placed particular emphasis on an effort to control postprandial excursions of blood glucose.

Patients

Twenty-five consecutive pregnant diabetics, aged from 17 to 41 (mean 25 years), took part. Four were gestational diabetics but the others were on treatment before pregnancy, all but one on insulin. The mean duration of insulin treatment was 10 years (range 1

month to 28 years). Nine patients had been admitted to hospital at least once because of ketoacidosis and nine at least once because of hypoglycaemia before the present pregnancy. Six patients had microvascular complications including two with proliferative retinopathy and two with persistent proteinuria. Of 14 previous pregnancies, six had resulted in perinatal death.

Two of the gestational diabetics were managed by diet alone, but all the other women were given insulin. Regimens were devised on an individual basis but usually consisted of two injections a day, each of soluble and isophane insulins.

Methods

Patients were taught to measure their capillary blood glucose concentrations using glucose oxidase strips (Reflotest) and a reflectance meter (Reflomat-Boehringer Mannheim). Emphasis was placed on careful individual instruction by an experienced doctor or specialist nurse. The patients were also taught to recalibrate the Reflomat meter with a standard glucose solution supplied by the manufacturer, and the accuracy of their results was checked occasionally by comparison with simultaneous laboratory estimations of venous blood glucose. As a further check on technique and accuracy, some patients kept their test strips for later inspection.[10] Reflotest does not give accurate readings below blood glucose concentrations of 3 mmol/l (54 mg/100 ml). Most patients rounded results below this range to 3 mmol/l. Where they recorded values below 3, we have arbitrarily counted them as 2 mmol/l (36 mg/100 ml). A reagent strip is now available with a range of 0·5-8 mmol/l (9-144 mg/100 ml) (Reflotest-Hypoglycemie), which is very suitable for use in pregnancy.

Blood glucose profiles were drawn from measurements made before and one and two hours after each main meal, at bedtime, and occasionally at about 3 00 am. Well-controlled patients repeated measurements every fortnight until the last trimester, when the frequency was increased to once or twice each week. If control was unsatisfactory at any time treatment was adjusted and measurements repeated, if necessary every day, until good control was restored.

Patients were supervised at a special clinic, where they were seen jointly by physician, obstetrician, and specialist nurse. Between clinic visits the nurse could discuss blood-test results with patients on the telephone and occasionally visit them at home, adjusting treatment as necessary. The aim was maximal surveillance with minimal disruption of family life. Patients were not admitted routinely at any stage of pregnancy. Obstetric problems, however, such as hypertension, were indications for immediate admission, as were persistent difficulties with diabetic control. When patients did have to be admitted they continued to monitor their own blood glucose concentrations while in hospital.

After 32 weeks patients were seen in the joint clinic every week. Oestriol excretion and human placental lactogen concentrations were monitored at each visit, and unstressed cardiotocography was also arranged each week. Ultrasound scanning was used from early pregnancy to monitor fetal growth. Amniocentesis was performed at 37 to 38 weeks for determination of the lecithin concentration of the amniotic fluid. Abnormal presentation or previous caesarean section was considered an absolute indication for operative delivery. If the lecithin concentration indicated fetal lung maturity, however, and the cervix was favourable labour was induced the day after amniocentesis with a view to vaginal delivery.

Results

DIABETIC CONTROL

Blood glucose measurements made by patients using Reflomat meters correlated well with simultaneous laboratory determinations ($r=0.86$ for 79 comparisons). The 25 patients made 4247 blood glucose measurements. The distribution of the results both at home and in hospital at all stages of pregnancy is shown in table I. The overall mean was 7·1 mmol/l (128 mg/100 ml) and the standard deviation 2·6 mmol/l (47 mg/100 ml).

The mean blood glucose profiles of the 20 patients who were already taking insulin (table II) illustrate the increases after meals and the tendency for blood glucose concentrations to be higher before breakfast than before other meals.

There was no statistically significant difference between the blood glucose concentrations of patients at home and in hospital (table III). Insulin requirements doubled during pregnancy from 47 to 95 units a day. Six patients had a total of 12 serious hypoglycaemic reactions needing medical attention. All but two occurred before the 20th week and several before pregnancy had been formally diagnosed.

OUTCOME OF PREGNANCY

Our patients spent an average of 22 days in hospital before delivery. Five were admitted for seven weeks or longer, two early in the study

TABLE I—*Results of 4247 blood glucose measurements made by 25 diabetic patients during pregnancy. All measurements after as well as before meals are included. Readings below range of the Reflomat meter (3-20 mmol/l) were counted as 2 mmol/l*

Blood glucose concentration (mmol/l)	2–	3–	4–	5–	6–	7–	8–	9–	10–	11–	12–	13–	14–	15–	16–	17–	18–	19–	>20
No of measurements	57	214	428	781	767	686	467	273	207	135	80	48	34	31	9	10	7	1	12

Conversion: SI to traditional units—blood glucose: 1 mmol/l ≈ 18 mg/100 ml.

TABLE II—*Mean blood glucose profiles of 20 insulin-dependent diabetics. Reflomat results (mean values) from all stages of pregnancy are included, both before and after insulin doses were adjusted to secure optimal control*

Patient No	On rising	1 h after breakfast	2 h after breakfast	Before lunch	1 h after lunch	2 h after lunch	Before evening meal	1 h after evening meal	2 h after evening meal	Before retiring	During night
3	5·7	9·3	8·4	7·0	7·8	8·2	6·6	7·3	6·7	7·5	9·3
4	5·5	7·2	8·0	5·7	8·4	8·1	6·5	7·5	6·5	5·2	5·1
5	5·6	8·7	7·0	5·4	6·7	6·7	6·8	7·9	6·6	6·4	4·8
6	6·9	7·7	7·1	6·5	7·4	7·2	6·6	7·1	6·9	7·2	6·0
7	8·4	11·4	10·2	7·6	7·8	6·7	6·6	7·5	7·5	7·1	6·0
8	7·5	9·1	8·4	6·2	7·6	6·1	5·7	7·0	6·5	6·7	5·5
9	6·8	10·0	8·6	7·2	8·4	6·8	5·9	9·0	6·6	6·2	3·8
10	5·2	6·4	6·2	5·2	5·6	5·2	5·0	5·2	5·4	5·6	5·4
11	7·7	12·0	9·0	6·0	7·4	5·7	5·4	7·4	7·3	7·2	4·6
12	11·5	10·5	6·1	4·3	6·1	6·0	5·2	8·0	7·6	7·3	6·6
15	5·6	8·1	8·2	6·0	7·4	7·6	7·1	7·6	7·5	6·4	
16	7·4	10·7	8·4	6·8	9·3	8·8	6·5	9·0	7·9	5·8	
17	6·0	8·4	6·5	6·8	8·4	8·0	6·2	7·2	6·7	6·6	3·6
18	6·2	7·0	6·7	6·3	6·1	6·0	5·6	5·5	5·6	5·4	5·9
19	6·7	7·8	6·8	4·6	6·7	8·0	6·5	7·3	7·2	5·5	8·4
20	8·2	8·6	8·8	6·2	8·3	9·0	5·6	8·6	10·4	7·6	7·1
22	7·9	8·1	7·5	6·2	6·4	5·3	6·2	7·8	5·3	7·0	6·6
23	7·7	9·7	10·2	6·4	7·1	7·2	7·1	8·4	7·1	7·4	7·2
24	5·5	5·7	3·6	5·9	6·5	5·8	5·7	6·0	5·4	5·4	
25	4·9	6·6	6·0	5·6	6·6	7·1	6·6	6·0	5·2	5·9	
Mean	6·8	8·6	7·5	6·1	7·3	7·0	6·2	7·4	6·8	6·5	6·0

Conversion: SI to traditional units—Blood glucose: 1 mmol/l ≈ 18 mg/100 ml.

TABLE III—*Comparison of blood glucose concentrations at home and in hospital during 25 diabetic pregnancies*

	Home		Hospital		Overall	
	No of obs	Mean (±SD)	No of obs	Mean (±SD)	No of obs	Mean (±SD)
1st trimester						
All results	188	8·4 (3·6)			188	8·4 (3·6)
Preprandial results only	72	8·0 (3·6)			72	8·0 (3·6)
2nd trimester						
All results	1250	7·6 (2·8)	302	7·8 (3·6)	1552	7·6 (3·0)
Preprandial results only	547	7·1 (2·7)	134	7·0 (3·3)	681	7·1 (2·8)
3rd trimester						
All results	1311	6·7 (2·1)	1196	6·6 (2·3)	2507	6·6 (2·2)
Preprandial results only	614	6·2 (1·9)	507	5·9 (2·0)	1121	6·1 (2·0)
Overall						
All results	2749	7·2 (2·6)	1498	6·8 (2·7)	4247	7·1 (2·6)
Preprandial results only	1233	6·7 (2·4)	641	6·1 (2·4)	1874	6·5 (2·4)

obs = Observations.

Conversion: SI to traditional units—Blood glucose: 1 mmol/l ≈ 18 mg/100 ml.

when the obstetricians were still sceptical about the degree of diabetic control that could be maintained at home. The third was a woman of low intelligence in adverse social circumstances, and the last two were those with proteinuria who both developed pre-eclampsia. Seven patients spent less than a week in hospital before delivery.

There were 12 deliveries by caesarean section, 10 vaginal deliveries after induction, and three after spontaneous onset of labour. The most common indications for caesarean section were previous section (three patients) and pre-eclampsia (three patients).

The mean gestational age at delivery was 37 weeks and the mean birth weight 3200 g. Eight babies were above the 90th percentile of weight for gestational age. Six of the 25 had initial Apgar scores less than seven, and four required active resuscitation. No baby developed respiratory distress. One had symptomatic hypoglycaemia needing intravenous dextrose, and in four others capillary blood glucose concentration fell without symptoms to below 2·5 mmol/l (45 mg/100 ml) but responded to oral feeding. Twelve babies developed jaundice. Six were treated by phototherapy alone, but one needed a single exchange transfusion because of rhesus isoimmunisation. There were no neonatal deaths. Three babies had congenital abnormalities (pulmonary stenosis, an asymptomatic sacral sinus, and partially fused toes).

Discussion

Standards for blood glucose control in pregnancy have often been published but few workers have reported how far these have been realised in practice. Published results have mostly been preprandial measurements in hospital during the third trimester. In these circumstances Essex *et al*[2] achieved a mean blood glucose concentration of 6·2 mmol/l (112 mg/100 ml) and in a later publication[11] "an average blood sugar level of 4·9 mmol/l (87 mg/100 ml)," although in the latter no further details are given. Three-quarters of results in the large series reported by Jervell *et al*[7] were less than 6·1 mmol/l (110 mg/100 ml). Even fewer studies give details of results achieved in the first and second trimesters, but Persson reported that 61 of his 81 patients had mean fasting blood glucose concentrations below 8·4 mmol/l (150 mg/100 ml) during the second trimester.[12]

Our results provide the most comprehensive record of blood glucose control throughout pregnancy so far published, and compare favourably with other reported figures. During all three trimesters our patients maintained mean blood glucose concentrations, including those after meals, below 8·4 mmol/l (150 mg/100 ml). Most importantly, results at home were similar to those previously obtained in hospital in the third trimester, mean preprandial concentrations being 6·2 mmol/l.

Because of the difficulties of treating and monitoring diabetes at home it has been suggested that the necessary control can be achieved only by admitting patients to hospital at 32 weeks. This policy has undoubtedly succeeded in reducing perinatal mortality,[2 7] but admission is inconvenient for the pregnant diabetic and her family. Furthermore, the expense can be justified only if necessary levels of control cannot be maintained as an outpatient or if hospital admission has advantages apart from diabetic control. For example, it has been suggested that diabetes predisposes to pre-eclampsia and that rest in hospital is an important preventive measure.[13] Others, however, have reported encouraging preliminary experience with outpatient management,[6 14 15] and our results also do not indicate any advantages of routine admission to hospital. In all trimesters diabetic control in our patients was the same at home and in hospital. Only three developed pre-eclampsia, which was predictable in the two with persistent proteinuria.

Monitoring blood glucose concentrations at home was highly acceptable to our patients, who made an average of almost 170 measurements each. Only one resented doing so many and required special supervision; she was an example of Pedersen's "neglectors"[8 16] who had lost a baby at 33 weeks through ketoacidosis. Most patients learnt the technique quickly, but it must be emphasised that accurate results are possible only if patients are individually taught and carefully supervised. The inclusion of a diabetes nurse specialist in our group was invaluable.

Diabetic control in the first trimester, during the period of organ development, may have an important bearing on the incidence of congenital abnormalities.[17 18] Relatively few of our patients were seen before 14 weeks of pregnancy, but when we have used blood glucose monitoring at home in the first trimester we have found it possible to obtain an equivalent degree of control to that achieved in the second.

Particular problems shown by self-monitoring were high fasting blood glucose concentrations and excessive peaks after breakfast. Attempts to lower fasting blood glucose concentrations by giving increased doses of isophane before the evening meal were often frustrated by nocturnal hypoglycaemia.[19] When this has been a problem we have found that giving soluble insulin before the evening meal but delaying the evening isophane injection until bedtime has produced more physiological free insulin profiles and lower fasting blood glucose concentrations without nocturnal hypoglycaemia. Measuring the blood glucose concentration at home at 3 00 am is a satisfactory way of detecting the need for a third injection. It is generally possible to avoid serious hypoglycaemia as an outpatient, although we have always taught our patients' husbands how to administer glucagon.

Our experience with home management in this small but unselected group of patients has been sufficiently encouraging for us to continue. Both doctors and patients have found the information obtained by home monitoring invaluable. It produces greater understanding and motivation among the patients, improving control early in pregnancy and shortening hospital stay. The wider availability of cheaper machines should make this method of care an attractive proposition for any diabetic woman contemplating pregnancy.

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Contemporary Themes

Nuclear medicine in district general hospitals

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Summary and conclusions

Nuclear medicine is a recognised clinical specialty both nationally and internationally. Compared with other countries, it is inadequately developed in Britain, particularly in district general hospitals. To create clinical radioisotope services at district level physicians or radiologists with experience in nuclear medicine need to be trained and appointed. Such appointments would allow facilities to evolve that would provide either a comprehensive nuclear medicine service formed around a physician or an imaging service based on a radiologist. Such units would improve the care of patients at a reasonable recurring cost of £15-£30 per investigation.

Introduction

Nuclear medicine is recognised by the Department of Health and Social Security as a specialty, and there are 22 established consultant posts in Britain. In addition, 10 senior registrar training posts are recognised by the Joint Committee on Higher Medical Training. The interests of the specialty are promoted by the British Nuclear Medicine Society, which has some 200 members. This organises a two-day annual scientific meeting, at which 400 participated this year. Last year, when its annual meeting was arranged jointly with the European Nuclear Medicine Society, 800 attended.

Thus in Britain a start has been made in developing an important part of clinical medicine, but the specialty has not progressed as far as in many other countries. The specialty is recognised by the World Health Organisation, which, jointly with the International Atomic Energy Authority in Vienna, produced a report entitled the *Use of Ionising Radiation and Radioisotopes for Medical Purposes (Nuclear Medicine)*.[1] In the United States and Canada nuclear medicine is well established, there being a formal system of training and examination of doctors by a conjoint board of nuclear medicine (formed by the boards of internal medicine, radiology, and pathology). Australia and New Zealand have a similar training system based on the Royal Australasian Colleges of Physicians, and each major city in these countries has at least one nuclear medicine consultant to supervise the clinical work concerned with radioisotopes. Closer to home, many European countries have more nuclear medicine consultants per head of population than we do. For instance, there are 58 in Czechoslovakia—four times the ratio in Britain. The EEC has not yet recognised nuclear medicine as a specialty although an application for it to do so has been made from Britain and Eire and this is being supported by countries including France, Italy, and Germany.

In its widest form nuclear medicine embraces all the medical uses of radioisotopes, including in-vitro as well as in-vivo techniques. In many hospitals the in-vitro techniques are carried out in departments of biochemistry, chemical pathology, or general pathology. In Britain nuclear medicine in 1979 embraces the following aspects.

Radioisotope imaging—both static and dynamic imaging and function.

Radioisotope non-imaging function tests—including Schilling tests and tests of gut protein and blood loss, red cell survival, and thyroid uptake (and scan).

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